The Design, Simulation, and Operation of a Comfortable Inside Climate for a Standard Office

P. Simmonds, RTB Van Heugten BV, Groningen, The Netherlands

Building operation strategies can greatly affect occupant comfort and energy use. Building simulation tools can provide the system designer with detailed information about the dynamic behavior of the building. With this information, the designer then can optimize the capacity and operating schedules of the HVAC system to take advantage of the thermal mass of the building.

The prediction of human comfort has been an area in which extensive research has been carried out and that requires calculation of various factors in the occupied zone. Analysis of the thermal environment requires a complete solution to the equations representing air movement and thermal response of the room under dynamic conditions.

Using a dynamic simulation computer program, various configurations were simulated, which resulted in an optimum design being achieved based upon comfort conditions and not temperatures. This paper shows how different fabric construction, glass type, sun shading, and air conditioning systems were simulated, resulting in an optimal design and operating strategy for a comfortable inside climate throughout the whole year.

Improved Visual and Thermal Comfort in Office Buildings

D. M. Rowe, University of Sydney, Australia

Dissatisfaction with the indoor environment of deep planned, artificially lighted, and mechanically ventilated office buildings continues to be widely expressed. Workers complain of poor lighting, ventilation, and thermal comfort and are concerned about potential impacts on health. Employers find rearrangement of interiors difficult and costly. Sections of the public are alarmed at the high rates of energy consumption needed to maintain habitable conditions. A view is emerging among some researchers that loss of individual control of the personal environment is at least partly responsible for worker discontent. A scheme to address these issues is described.

The author proposes that baseload lighting, ventilation, and cooling requirements be met by ambient lighting and air distribution and that these be supplemented by additional local illumination, ventilation, and thermal control which would be delivered by occupant-controlled light sources and air outlets built into workstation furniture. All services necessary at the workstation would be conveyed by an "umbilical cord" connected to a readily demountable outlet on the ceiling to facilitate rearrangement. The worker at the station will be able to exercise control over direction and rate of flow of conditioned air and intensity and direction of light. It will be shown that adoption of such a system can result in a 15% reduction in energy demand compared with systems for uniform overall illumination and thermal control.

Daylight Models for the Northerly Latitudes

T. Muneer, R. C. Angus, Napier University, Edinburgh, UK
R. S. Webb, Heriot Watt University, Edinburgh, UK

International Daylight Measurement Year, a program endorsed by the International Lighting Commission and supported in Britain by the National Illumination Committee and the Chartered Institute of Building Service Engineers, was designated in 1991. The object was to set up daylight recording stations around the UK in a manner that would highlight climatic and latitude differences. The basis for this proposal was that no data on the distribution of diffuse illuminance existed outside the southeast of England, and no statistical records of sky luminance distribution existed anywhere in Great Britain.

The measurements at these stations are to be taken at one-minute intervals instead of the previously normal hourly recordings.

The authors have established the first Scottish daylight and solar irradiation monitoring station in Edinburgh. Further, two control stations are being set up, one at Napier University and the other at Heriot-Watt University. This article will present investigations carried out with respect to the correlations between diffuse and beam illuminance and irradiation, their latitude dependence, and the effect of microclimate. The integration of these correlations in daylight design packages will also be addressed.

Intelligent Building and Global Approach of Comfort: Development of a Simulation Tool

P. Michel and M. Regard, Ecole Nationale de Travaux Publics de L'Etat, Vaulx en Velin, France

Domotics has had a large commercial expansion in the last five years and industrial products are now numerous and varied. But these so-called "intelligent" systems do not always adequately coordinate the different functions they must fulfil. It is then important to define control algorithms for these main functions (heating, lighting, ventilating, and home and people security) which can provide the essential comfort to the occupants of a dwelling, the main component of modern life quality.

A systematic approach to the intelligent building, highlighting its complexity, is taken as a basis for the development of a simulation tool. A first step for this laboratory tool, based on a very simple hypothesis, allows the thermal management of the dwelling aiming at keeping a comfort temperature. A second step, while approaching a real dwelling through several different areas (night rooms and day rooms, life rooms, and service rooms), develops the idea of a global comfort: simultaneous management of different variables (temperature, humidity, CO_2, etc.), several occupants taken into account in the definition of thermal comfort, and control of artificial lighting linked to natural lighting.

Demonstration of Airborne Irritant Chemicals in Indoor Air

R. C. Anderson, Anderson Laboratories Inc., Dedham, MA, U.S.A.

Symptoms of exposure to irritant chemicals are similar to many indoor air complaints. Perhaps airborne irritant chemicals contribute to the sick building syndrome. To test this hypothesis, a toxicology method which estimates potency of airborne irritant chemicals (American Society for Testing and Materials E-981) has been applied to indoor air samples. E-981 data have been extensively measured against human exposure and response data, and they predict human responses to irritants with excellent success.

Air samples were collected in Tedlar gas-sampling bags from noncomplaint (Group 1) and complaint (Group 2) sites. The air was tested for irritants. None of the Group 1 samples contained irritants of potency sufficient to cause human symptoms. In Group 2, 18 out of 20 air samples caused moderate irritation (human symptoms: headaches, fatigue, eye irritation, and difficulty breathing). The two nonirritating Group 2 samples were from a room in which the occupant had suffered from a severe allergic response rather than irritation. Another Group 2 sample caused animal death during testing. We conclude that ASTM E-981 is sufficiently sensitive to diagnose airborne irritant chemicals in some of the indoor sites causing human complaints.

Demonstrating Maximum Energy Efficiency in Commercial Buildings

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A large U.S. electric and natural gas utility began a project in 1990 to determine the economically achievable energy savings attainable by using new energy-efficient end-use technologies and systems in utility customer's facilities at costs competitive with the utility's energy supply costs. The Advanced Customer Technology Test (ACT²) for Maximum Energy Efficiency research project is using a field-based demonstration approach to provide information on the maximum energy savings possible when packages of new high-efficiency end-use technologies are integrated into commercial and residential buildings, both new and retrofit.

The project has three constraints: the systems' benefit to cost analysis must be consistent with power generation investment criteria, the systems must be acceptable to the utility customer, and the systems must demonstrably be the maximum energy savings design within the first two constraints. The research project is monitoring the entire breadth of maximum energy saving design, from the design approaches and installation techniques to monitoring of all aspects of the building, energy end-use through detailed environmental qual-

ity parameters and occupant acceptance of the new measures adopted. Results from the pilot sites, a 22,000-ft² (2,044 m²) commercial retrofit and the first commercial new construction site, a 17,000-ft² (1,580 m²) office, indicate potential savings of over 70% of the building's current or projected energy use without altering the occupants' comfort level or environmental conditions. This paper presents the underlying rationale, approach, and results to date from the initial commercial sites of the ACT² project.

Experimental Exposures to (1-3)-ß-D-Glucan

R. Rylander, University of Gothenburg, Sweden

Previous epidemiologic investigations have demonstrated a relation between the extent of symptoms in sick buildings and the presence of (1-3)-ß-D-glucan—a cell wall constituent of molds.

Experiments were undertaken where persons with and without reported symptoms in buildings were exposed to an aerosol of bacterial endotoxin or (1-3)-ß-D-glucan for four hours. Symptoms were recorded in terms of severity using a questionnaire before, during, and after the exposure.

The results showed that symptoms of nose congestion were reported after exposure to endotoxin or glucan in the sensitive group and that headache and skin redness was reported in the sensitive group but only after exposure to (1-3)-ß-D-glucan. The results are preliminary, but they suggest that some of the symptoms typical for sick buildings may be provoked by endotoxin and (1-3)-ß-D-glucan in concentrations equal to those found in the environment.

An Integrated Software for Building Design

P. André and J. Nicolas, Fondation Universitaire Luxembourgeoise, Arlon, Belgium

Many computer simulation tools are available today to calculate building energy performance. However, most of these tools are not used in the current practice because they require substantial work to input the data and technical skill to properly use the program and analyze the results.

To make building simulation tools more usable by designers, architects, and engineers, a project has been launched to develop an integrated software for building design. This software gathers several tools in the field of building analysis: a computer aided design software, a building material database, several thermal simulation programs, and an expert system.

The different tools are organized around a central database containing an object-oriented representation of the building which grows during the design process. An original feature of the software is dealt with: each program is "plugged" in the system through a specific interface or driver. The system is also provided with a user friendly interface, allowing easy access to the different components of the program. The first version of the program is available to deal with simple (monozone) buildings. Further work will develop the multizonal capability to handle more complex buildings.

Simplified Models of the Thermal Behavior of Buildings

P. Matiasovsky, Slovak Academy of Sciences, Bratislava, Czechoslovakia

In recent years, a number of different approaches to the modelling of thermal behavior in passive solar buildings have been published. The common feature of these models is that they issue from an ordinary differential equation of the thermal balance in building periodical time-variable boundary conditions. The periodical boundary conditions enable certain simplification in expression of differential equation parameters. However, they are not typical for European climates. When modelling thermal behavior of buildings, it is necessary to consider interdiurnal changes of climatic elements during the year. Such a model is presented in the paper.

A Design Tool to Optimize the Applications of Legal Issues in Building Construction

S. A. Avila and D. C. Avila, Consultants, Barcelona, Spain

This paper describes a study to develop a methodology, parameters, and the technology to optimize the application of legal issues in building construction. A partial result of the research is described as well as a utility for computer aided design drawing as a support to the architectural design. This software has been used for checking and evaluating the environmental impact in accordance with the legal issues of a semitemperate region in Mexico. A case study has been carried out to check the proposed method and selected parameters and techniques.

Enhanced Energy Management Strategy of the Advanced House Project in Quebec

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N. Bigras and L. Muyldermans, Association Provinciale des Constructeurs d'Habitation du Quebec, Anjou, PQ, Canada

The Canadian Standard R-2000 for energy-efficient houses determines the energy consumption of residential units in the range of 100 kW·h/m² per year. The Department of Energy, Mines and Resources Canada (EMR) recently initiated a competition to enhance this standard. The purpose also is to demonstrate that an advanced house can offer a better quality of life regarding indoor air quality, natural lighting, and the use of environment friendly materials. The authors were awarded a grant from EMR for the realization of the project in a Montreal suburb.

The technical aspects of the house are described, giving the details of the energy flows through its different subsystems. The advanced house integrates the following main mechanical systems: a ground source heat pump for heating and cooling, an independent sunspace adjacent to the house with a swimming pool used in winter as an energy buffer, a ventilation and heat recovery system, and an evaluated tube solar system.

These elements are interconnected in four different modes of operation: heating mode, pumping the energy first from the pool maintained as cold as possible, then from the ground; heat recovery from the house, from the solarium, and from the active solar system to the pool; free cooling during spring and summer, using the ground; and air conditioning during summer heatwaves only.

A detailed monitoring program of the advanced house is to include air quality measurements, one-time tests on the building envelope, and a performance evaluation over two years. The points of measurements have been chosen to determine which elements of the advanced house are the most cost effective and therefore worth further investigation for technology transfer.

Habits of Users in Dwellings During Heating Period According to Indoor Comfort

D. Petras, Slovak Technical University, Bratislava, Czechoslovakia

The main aim of the experimental evaluation was to obtain results according to habits of users in dwellings during heating periods from two aspects: energy conservation and indoor comfort. A questionnaire was used to evaluate indoor comfort, with specific considerations of thermal sensations, air exchange rate, and thermal adaptability. Energy consumption was measured by a control system in each of 30 flats.

CFC Recovery and Prolonged Use of Existing Refrigerators

A. Takla, University of Liege, Liege, Belgium

About 10 million used refrigerators are destroyed annually in Europe. Of these, 10-30% may have a successful life in the range of 15 years if the related compressors, thermostats, and gaskets are replaced by new ones. Only two central plants for destruction of used refrigerators and recovery of chlorinated fluorocarbon (CFC) exist in Europe. CFC is recovered from the refrigeration circuit as well as from the insulating materials. Postponing the destruction of a refrigerator by 15 years means a real benefit for the environment in terms of ozone depletion potential and global warming potential. It also represents an important benefit for developing countries which will use these refrigerators. The paper will discuss this idea and its preliminary techno-economic feasibility.

Detection and Resolution of Acoustical Problems in Buildings

G. De Mullewie, CEDIA, Liege, Belgium

According to an Organization for Economic Cooperation and Development (OECD) estimate, at least 15% of the population (130 million people living in OECD countries) suffer from problems related to pollution because of exposure to unacceptable levels. In many cases, noise pollution may be more important for the population than air or water pollution. It is certain that there are many ways to solve these problems. One of these is to improve the acoustic comfort of buildings.

The first objective of this paper is to identify the acoustic problems usually encountered in buildings, such as walls and partitions too light, contour problems, false-ceiling problems, poor choice of windows, or technical equipment problems.

The second objective is to show that if these problems are detected at the preliminary (planning) stage they can be solved without excessive cost increases. For each particular problem, solutions will be given and calculations and design principles discussed. The legislative and standardization issues also will be discussed.

UV Sterilization for Air-conditioning Systems

O. Declercq, C. Delvosalle, and M. Vanthournhout, Faculté Polytechnique de Mons, Mons, Belgium

Great amounts of various contaminants are trapped in the humidifier water of air conditioning systems, resulting in the proliferation of numerous microorganisms. Spreading of these microorganisms through aerosols carried by the air distributed in the buildings may cause human contamination (e.g., humidifier fever and Legionnaire's disease).

Preliminary studies showed the efficiency of ultraviolet (UV) sterilization applied to an air humidifier consisting of textile cable curtains stretched vertically. The liquid distributed at the top of the curtains forms around the cables' thin pipes and falls at uniform velocity. UV lamps are positioned horizontally and symmetrically in front of the cables to ensure a good distribution of the UV light. This installation, operated in a bank office building located in Brussels, created a decrease in microorganism concentration in the humidifier water from 10^4 microorganisms per milliliter to 20,000 microorganisms per milliliter in less than one hour, consequently reducing the microorganism concentration in the air distributed in the building to a rather low value under 20 microorganisms per cubic meter. This situation can be maintained during long periods.

Characterization of Volatile Organic Compound Emissions From Construction Products

S. Kirchner and C. Cochet, Centre Scientific et Technique du Baitment (CSTB), Champs-Sur-Marne, France

Appreciable amounts of organic vapors are released into indoor air from a variety of decorating and building materials. Exposure to these products may have long-term health effects ranging from discomfort to illness. Little data now exists concerning health risks or characterization of the products themselves. This is partly due to the complexity of the problem: variability of emitted compounds in space and time along with low concentration levels.

Cleaner indoor air can be obtained by reducing vapor sources and optimizing ventilation systems. Many architects, designers, building owners, and tenants may now wish to control indoor air quality (IAQ) through a careful choice of materials used in building and decorating. Thus, there is a surge for developing harmonized emission testing protocols allowing an international product-by-product comparison. CSTB has set up a volatile organic compounds emission test facility for building products characterization. Products are being tested in realistic conditions using small test chambers highly controlled for environmental parameters.

Chemical analyses allow chemical identification of the compounds, emission rate calculation, and time variation of the results. From this data, the indoor air concentration of each pollutant can be developed and disseminated. Manufacturers will use it to modify their products to stay competitive in a market where IAQ has become a key factor.

The Basis of the Ventilation Regulation for Residential Buildings in France

J. G. Villenave, J. Riberon, and J. R. Millet, Centre Scientific et Technique du Baitment (CSTB), Champs-Sur-Marne, France

For more than 20 years, French regulations for dwellings have been the catalyst for ventilation technological progress. For instance, in 1969 ventilation had to supply fresh air to the habitable rooms and exhaust stale air from the service rooms (this point of the French regulation has been continuously used since) with an air change rate of about 1 volume/hour; the technological consequences were the use of self regulated inlets and outlets.

After the energy crisis of the 1970s, research on occupied dwellings revealed that almost 50% of dwellings were over ventilated; with the 1982-83 regulation the flow rate depends on the number of habitable rooms, with the possibility of reducing the ventilation rate during times of less occupancy. One of the technological consequences is the development of humidity controlled ventilation systems.

The authors describe how basic studies (detailed simulations) have been used to define the calculation of energy losses due to ventilation. The ongoing research seeks a better assessment of air quality.

A Design Procedure for High-temperature Heating Panels

P. Brunello, University of Udine, Italy
R. Zecchin, University of Padova, Italy

High-temperature heating is becoming more and more popular for applications in large buildings (atriums, trading centers, industrial sheds, etc.) since direct infrared radiation, compared with other systems, allows for obtaining a lower room air temperature with almost no stratification. However, the dominant radiative effect over thermal comfort makes the correct sizing of the terminal units quite difficult since the standard calculation procedures of heat losses are based on the assumption of indoor air temperature.

A detailed calculation model solving the thermal balance of a room with high-temperature heaters has been set up as described in this paper. By means of this model, easily implementable on any personal computer, both heat losses and comfort conditions can be calculated.

To make the selection of the terminal units even easier, suitable graphs (obtained by applying the model to a large variety of buildings) relate the actual heat losses to the activity and clothing of the inhabitants.

Heat Demand Patterns in Dwellings

M. E. Boonstra, University of Amsterdam, Amsterdam, The Netherlands

Heat demand patterns in dwellings, which reflect the dynamics of heat demand over time, were simulated over one year by means of a simplified thermal dynamic building model. Parameters used related to physical determinants of heat demand patterns such as solar radiation, outside air temperature, and building characteristics, as well as to determinants of human behavior, including thermostat settings and ventilation rates.

Simulation results were verified against two sets of measured data for complexes of inhabited dwellings in The Netherlands. It appears that heat demand patterns over a year can be simulated satisfactorily, mainly by adjusting the behavior parameters.

The simulation model developed has been applied to study the effect on heat demand patterns of changes in orientation of the building and of alterations in physical characteristics of the building such as improved insulation. In the case of improved insulation, results show changes in heat demand patterns and a clearly shortening of the heating season. The model also can predict the changes in heat demand patterns caused by behavioral change. Furthermore, the model has been used to study the feasibility of heat supply options such as cogeneration or heat pumps. Reduction in

heat demand appears to have a considerable influence on the application of heat supply options.

The Model of Season Energy Consumption Caused by Air Infiltration in Huge Single-room Buildings

J. Sowa, Warsaw University of Technology, Warsaw, Poland

The presented model is based on experiences from the research program on experimental reconstruction and modernization of industrial building regarding energy consumption limitation. The program indicated that a magnitude of air leakage through the envelope, as well as its variability, were a very undesirable disturbance significantly affecting rational energy management and the processes of creating acceptable indoor air quality.

In the proposed model, energy consumption is estimated as a sum of momentary heat requirements accounted with selected steps (usually one hour) for disturbances generated slochastically. Momentary values of air infiltration rates are estimated by a computer program built on theoretical network flow models.

The model has been constantly verified in a test industrial building, which has been air sealed, reconstructed, and modernized during research. Season heat energy consumption for the conditions before reconstruction was about 1270 GJ/A (47% of the total value of 2690 GJ/A). Air sealing of the envelope has reduced that estimated value to 190 GJ/A (31% of the total value of 622 GJ/A). During the heating season of 1990-1991 (higher than standard ambient temperatures and bigger than usual internal gains), the total heat energy consumption was measured as 510 GJ, with a similar estimated contribution of air infiltration.

Analyses of seasonal energy consumption, as well as complementary analysis of momentary heat requirements variability and estimations of potential transport of pollutants that have been carried out, show that problems may be reduced in those buildings in which the envelope successfully divides indoor areas from the ambient environment.

Modelling and Control of HVAC Systems in Large Commercial Buildings Under Dynamic Rates

S. K. Mukherjee, ORIAICON International, Cupertino, CA, U.S.A.

A methodology for modelling the HVAC system and for developing an optimal scheduling and control system in commercial buildings is discussed in this paper. The Building Energy System Model (BESM) relating the evolution of temperature at various zones in the building to building characteristics, external weather variables, and the operation of the HVAC system is based on statistical analysis of experimental data collected from the building. The model coefficients of BESM, following the properties of a linear dynamic system, are estimated from such data using a special computer software. The Optimal Scheduling Model (OSM) is a linear program incorporating BESM and additional constraints. An OSM solution optimizes the operation of the HVAC system to reduce monthly bills under a dynamic rate structure for electricity.

Energy Conservation in an Air Conditioning Facility

S. M. Sule, HVAC & R and Energy Management, Ahmedabad, India

The objective of the energy audit was to conserve energy in a production facility with air conditioning systems consuming a major portion of the total energy. A systematic, year-round recording of the energy consumed by various manufacturing and supporting activities was completed. This was followed by an analysis of the energy consumptions for identifying the following key results: yearly based demand (kW·h), energy consumption (kW·h per 1000 units produced), monthly peak demand (kW), and energy consumption and peak demand in peak winter and peak summer to assess the lower and the upper limits of loads on the air conditioning system.

Observations showed: the control system of the air conditioner was ineffective; the refrigeration systems used single-stage reciprocating compressors; large, centralized pumps supplied cold brine to various facilities while 80% of the loads occurred simultaneously; and large tube-well pumps and air compressors meant for the supporting activities operated simultaneously with the equipment meant for the production facility.

Several different procedures are possible that would help to rectify these problems: improved control system, two-stage compressors, separate, smaller pumps to handle cold brine quantities, recovery of energy from the heat of rejection, or equipment for supporting activities programmed to operated during off-peak hours.

In conclusion, the authors found that (a) the regular energy audit opened new avenues for energy conservation; (b) the intelligent control systems saved energy; (c) recovery of energy from the heat of rejection was cost effective; (d) capacities of equipment should be selected after analyzing full loads, partial loads, and load factors; and (e) before starting a manufacturing activity an analysis of the air conditioning system for operating costs is useful since it identifies an important component that influences the cost of the finished product.

Natural Ventilation

J. Arts, Colt International, Mechelen, Belgium

Natural ventilation is a highly controversial way of venting. An elementary way of venting, it's not exactly calculable, not manageable, and not universal. This presentation discusses the advantages and disadvantages of using natural-ventilation buildings.

In any building the primary target for ventilation is to provide optimal conditions, whereas the secondary target is to protect manufacturing processes, productes, or materials.

Specific advantages of natural ventilation in relation to mechanical ventilation include: fewer architectural provisions are needed, lower investment and debt, lower operational costs, longer life, less sensitivity to disturbance, less maintenance, low noise, and extra daylight provided.

However, natural ventilation is not suitable in working spaces where, in addition to heat overload, climate is seriously disturbed by low pressure, vapors, gases, excess fluid, and dust. However, it is perfectly suited in working places in heavy industry, exhibition buildings, shopping malls, atria, social workshops, and drilling platforms.

Ground-coupled Building Design Using the Inverted Cave Concept

T. E. Loxley, Inverted Cave Education, Frederick, MD, U.S.A.

This concept of energy saving, low-rise buildings is based upon geophysical research into the effect of soil moisture transport on upward heat transfer. In effect, it exploits rising dampness to thermally couple the interior of a special building envelope to the local subsoil. This extended insulation envelope, which encloses an isolated soil column, is used with a two-step heat-loss design procedure.

The soil column is covered with a plastic membrane and concrete, much like a standard monolithic slab foundation. The membrane and a perimeter drain control excess moisture and any radon that might be emitted. A foam-plastic insulation skirt, equivalent to the above-grade wall insulation, extends to the base of the foundation.

The first design step matches the building heat loss, at an inside temperature equal to the local subsoil, to 35 W/m² from its horizontal contact. The second step then determines how much added heat is required for the comfort desired. The full system adds a serpentine loop of 100-150-mm-diameter plastic pipe on top of the soil column to store and circulate water and a modest wall-mounted solar collector. The water is used with a standard electric water-to-air heat pump to provide forced-air heating and cooling.

Independent 1988 consumer tests of a 223-m², two-story test house documented a 700-kW·h annual space heating consumption in a 28°C (18°C base) heating climate with a two-year payback of the added construction cost. The concept is especially practical with the use of autoclaved aerated concrete and the European-style turnkey building company. The paper illustrates the inverted cave design of a single-family home, a central-atrium school, and a three-story apartment building.

Friday, February 19

Session Eight: 8:30-10:15

OPTIBAT: A Real Scale Cell in Simulated Climatic Environment for Multizone Air Flow Patterns in Buildings

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P. Depecker and F. Allard, CETHIL-URA CNRS 1372 INSA, Villeurbanne, France

One of the main problems about air-flow-pattern studies remains the experimental validation of the numerical codes developed for interzone air flow and pollutant diffusion prediction.

A few years ago, CETHIL developed a real-scale experiment made of an 88-m^2 dwelling built in its laboratory hall in a controlled-climate environment. This experimental tool allows full control of outdoor climatic conditions: air temperature, relative humidity, and pressure drop. Pressure drop can be controlled on the six faces of the cell. Thus, OPTIBAT is a reference tool for multizone air-flow measurement techniques, making experimental data sets available for validation of numerical models.

The first phase of this project allowed us to determine air leakage characteristics of indoor and outdoor walls of the cell.

The second element required the validation of multizone flow codes, the knowledge of all interzone air flows. The vast majority of the air-flow measurements made to date have involved multiple tracer-gas techniques. Using the OPTIBAT facility, we have used only one tracer gas to determine all the air flows.

This report describes the experimental cell and gives the first results of air-flow measurements using the tracer-gas technique. The interzone air flows are computed using two methods. Each method is completed by an error analysis which defines the uncertainty of each result. Both methods give the same results.

Indoor Air Quality and Well-being in the Operating Theater

I. Holcatova, Medical Faculty Charles University, Prague, Czechoslovakia

The surgeon's work in the operating theater is exacting of both professional knowledge and physical and mental conditions. Besides other factors, the mental well-being is also affected by indoor air quality, primarily the factors of the temperature-humidity microclimate. In the operating theaters of a Prague surgical clinic, individual components of the temperature-humidity microclimate were measured and microbial indoor air contamination assessed. At the same time, the mental well-being of the surgeons was established by guided inquiries. The results are presented. The conclusion is that doctors are dissatisfied with indoor air climate in the operating theater.

User and Occupant Controls in Buildings

W. T. Bordass and A. Leaman, William Bordass Associates and Building Use Studies, London, England

Energy consumption in recent UK commercial buildings is often higher and user satisfaction lower than anticipated, particularly in buildings with air conditioning. A series of interviews and questionnaire surveys of occupants and management have been conducted to gather data about energy use and the controls provided. The surveys reveal that:

- Many controls do not suit management and users, so systems run longer and less efficiently than they should, wasting energy.
- Many systems whose use should vary with demand default to fully-on when the requirement is only small or marginal. Once on, they tend to remain on as rational switch-off decisions are often difficult.
- The buildings surveyed with low energy consumption also have high occupant satisfaction; this is not cause and effect but two associated consequences of good management.
- Perceived comfort and control comes not so much from particular individual control devices but from systems that react rapidly when people want conditions to change.
- This rapid response can be achieved either by simple "domestic" controls (an openable window or light switch), well-configured electronics, or an effective manager. It does not necessarily need new individual control devices.
- Complaints about comfort and control are common where people are adversely affected by the actions of others not within their immediate working group or by automatic systems which make abrupt and seemingly capricious changes (e.g., adjusting sunblinds).
- Simplicity and comprehensibility is best.

Better configured controls offer great opportunities to improve comfort and save energy in both existing and new buildings. However, much more attention must be focused on design for manageability and usability. Otherwise, tommorrow's advanced "green" buildings may show similar problems of occupant dissatisfaction to yesterday's air conditioned ones.

Designing Buildings for Improved Indoor Air Quality

D. S. Walkinshaw, Indoor Air Technologies, Ottawa, ON, Canada

Problem solving in the indoor environment suggests revised approaches and criteria for designing buildings and their ventilation systems. This paper outlines some indoor air quality problems which can be encountered and suggests design, construction, operation, and maintenance measures for their avoidance or minimization. The development and performance of an engineered basement-construction envelope ventilation system is used to illustrate some of the design principles and construction measures involved.

Thermal Comfort Analysis in a Passive Solar Building

P. André, J. Nicolas, and B. Colson, Foundation Universitaire Luxembourgeoise (FUL), Arlon, Belgium

In 1986, the new building of the FUL Research Institute was completed. From 1988 to 1990, it was intensively monitored in the context of the International Energy Agency project "Passive Solar Commercial Buildings". In 1991, an additional monitoring effort was performed to evaluate (by means of the Fanger theory) the thermal comfort, especially in summer conditions. The objectives of the work were to evaluate summer comfort level [predicted mean vole, predicted percentage of dissatisfied (PPD)] in the current operation; to test the efficiency of several comfort control devices (external roller blinds, internal shutters, mechanical ventilation system, roof window opening); and to propose control strategies based upon experimental investigation.

Therefore, short (1-2 weeks) monitoring campaigns were conducted in four rooms of the building: the auditorium, meeting room, office, and hall. Results show that the comfort level is accurate in the auditorium and overheating is often recorded in meeting rooms and offices. The efficiency of the roller blinds activation is shown to be satisfactory at the price of reducing daylighting. The mechanical ventilation is efficient in the meeting rooms, changing the PPD from 40% to 25% in 10 minutes, but inefficient in the offices where the PPD remains unaffected. Other devices are shown to have a limited thermal comfort.

Artificial Illuminance: Some Differences Between Design and Reality

G. K. Cook, University of Reading, Reading, UK

This paper examines the findings of a lighting survey of 59 classrooms which was carried out as

part of a larger study on the differences between predicted and actual performance of artificial lighting installations. The methodology of the lighting survey will be described in detail and diagrams of interiors will be included. The results of the survey are compared to the illuminance and glare recommendations in three different artificial lighting design codes. This will show that many of the classrooms fail to meet the requirements of these guides. While recognizing that the codes offer imprecise guidance, the survey results indicate that poor-quality learning environments exist.

Using the data from the survey, an artificial lighting design for each room has been produced. The predicted illuminance in the rooms differs significantly from the surveyed illuminance, although the design included allowances for maintenance, reflectance, and floor and ceiling cavities. These allowances are based on information from the facilities managers and current UK design practice. A detailed examination of the reasons for these differences will reveal that certain methods of quantifying the influence of maintenance, reflectance, and obstruction in actual interiors is inappropriate. The need for further work to enhance their accuracy is identified.

Quantification and Visualization of the Air Flow Pattern by Using Image Analysis

D. Berckmans, K. Van de Weyer, and M. De Moor, Agricultural Engineering, Haverlee, Belgium

The process of air mass transport has an important influence on the resulting microenvironment within a building. To achieve an efficient transfer of energy and mass around the occupants, the air flow pattern should be controlled. To study the air flow pattern in a more quantitative way, a practical measurement technique should be available. In this paper, a method is presented to quantify and to visualize the air flow pattern in a room. The use of a low-cost camera is combined with an algorithm on a personal computer to automatically calculate the coordinates of an air jet and to visualize the dynamic behavior of the air flow pattern. So far, the method has been developed for a two-dimensional air flow pattern, but it should be possible to measure the three-dimensional coordinates as well. The method is described, and measurement results are presented.

Microbial Volatiles: A Causative Agent to Sick Building Problems

G. Ström, U. Palmgren, and J. West, Pegasus Labs, Uppsala, Sweden

In Sweden, due to highly insulated housing, damp conditions often occur within the building construction. This results in a nonvisible growth of fungi and bacteria. Complaints of moldy-like odors in Swedish housing are quite common and suspected to be one causative agent for complaints of eye, nose, and throat irritations.

Quantitative measurements of the airborne microflora in houses with moldy odors show no significant differences compared to houses without odor problems. On the other hand, microbial analysis of building materials show a high degree of contamination of both fungi and bacteria in houses with odor problems compared to reference houses. Volatile organic compounds, considered to be selectively produced by microorganisms, have been measured using gas chromatography and mass spectometry to trace deterioration caused by fungi and bacteria. Also, the penetration ability through tight materials used in Swedish buildings such as high-density polyethene sheeting has been investigated.

The results show a significant increase in the concentration of microbial volatiles in houses suffering from microbial problems compared to reference houses. For instance, many of the volatile compounds easily penetrate high-density polyethene sheeting used as water vapor barriers by diffusion. Therefore, they can penetrate tightly built construction, enabling contamination of the indoor air.

Session Nine: 11:00-12:30

Diagnosis and Management of Allergic Troubles Due to Poor Indoor Air Quality

M. R. Ickovic, Pasteur Institute, Paris, France

The increase in frequency of allergic diseases, more particularly with respiratory symptoms, has doubled in the last 15 years. This prevalence is probably due to a better screening of allergy, but also is caused by obvious environmental factors. In the past, outdoor air, public places, and industrial settings have been of particular concern. Residential indoor air quality is only of recent concern. However, new ways of life, new building technologies, and more concern about saving energy may play a major role in increasing frequency of hypersensitivity occurrence due to increasing amounts of allergens and pollutants. House dust mites, pets, molds, tobacco smoke, gas, and chemicals help to sensitize new subjects.

Diagnosis of allergies are quite easy with the help of modern *in-vivo* and *in-vitro* methods. However, the physician is often unarmed facing symptoms not involving known allergens. Sampling indoor air quality is not yet a routine procedure and is expensive. The author believes in prevention strategies which should be set up at many levels: building technology, choice of materials, insulation, ventilation, detection of the various risk factors, and sources of pollutants, information, and education of occupants.

HVAC Equipment: Alternative Solutions for Refrigerants

A. Pilatte, Faculté Polytechnique de Mons, Mons, Belgium

All air conditioning systems, air cooled units, or water chillers, use refrigerating units. The most efficient refrigeration process is based on the forced vaporization of a liquid boiling at low temperature called the refrigerant. For economic, safety, and toxicity reasons, the refrigerant is enclosed in a sealed circuit of a vapor compression system or an absorption unit.

Being within or in the immediate proximity of the building to be air conditioned, the refrigerant must meet requirements for the local environment (it should not alter the health conditions of the occupations nor present fire or explosion risks) and the global environment (its ozone depletion potential and its global warming potential must be low). In fact, in the field of refrigeration, global warming not only will be affected due to emission of refrigerants into the atmosphere, but also by indirect effects due to emission of CO_2 resulting from their use. This indirect effect, therefore, is related to the energy efficiency of the refrigeration cycle.

The usual chlorine-containing refrigerants commonly used today will be abandoned to comply with international, national, or regional regulations. The consumption of our everyday refrigerants must decrease according to a given scenario. In the near future, most HVAC equipment will continue to rely on vapor compression cycles using acceptable substitutes, but technologies such as absorption and adsorption-desorption or evaporative cooling will take a small part of the existing chlorinated fluorocarbon market. The search for substitutes having low ozone depletion potential and low global warming potential values and leading to better energy efficiency is the actual task of the researchers in this field.

The properties of the alternative candidates to the refrigerants used in unitary air-cooled air conditioners and in water chillers are discussed with respect to both the direct effect on the environment and the indirect effects of carbon dioxide emission. Nonvapor compression cycles will be discussed on the same basis.

Experiences with Naturally Ventilated Atria

P. Simmonds, RTB Van Heugten B.V., Groningen, The Netherlands

The new teaching hospital in Groningen will be finished around the year 2000 and will have 1000 beds. In total, nine atria will cover the pedestrian areas. These atria are not heated or mechanically ventilated, not even during the summer. Smoke extraction openings in the roof provide natural ventilation.

The first atrium was finished in 1988. At that time, eight temperature recorders were placed inside; five measured the vertical temperatures and three measured air temperatures, which were influenced by solar intensities. Measurements also were continuously made of the outside air temperature, solar intensities, and the position of the openings (open or closed). Because the nine atria

will be linked to each other by pedestrian walkways, the inter-atria movement of air (if any) needed to be investigated. Computer simulations were used to simulate bulk air movements into and within the buildings, driven by wind pressures, buoyancy forces arising from internal and external temperature differences, and purposely designed mechanical ventilation systems (in the surrounding buildings).

Using the simulation model infiltration estimation, potential natural ventilation, and general patterns of air movement were determined. These results were then compared to the original design calculations to determine whether design, construction, or operational changes were necessary for the future atria.

The provisional results of the comparison concerning fresh air ventilation, total air ventilation, and low level/high level temperature differences all correspond within 5% of each other. It is expected that the difference between the results from the definite calculations and the actual recorded measurements will be less than 5%. If this is true, it will provide an exceptional design tool for future atria.

Building Energy Management Using Occupancy Prediction

G. Clark and P. Mehta, Brunel University, Uxbridge, UK
T. Thomson, Dunwoody and Partners, London, UK

This paper will outline a case study into the optimum energy management of services within a building using occupancy prediction. The aim is to "tune" the services within the building to best fit the requirements of the building's occupants at minimal cost. The work used the Lloyd's building in central London as a case study and looked at HVAC and lighting systems.

The approach uses the latest in computer "artificial intelligence" techniques. The system uses neural-network computing to "learn" occupancy levels and trends within the building, which are then used to predict occupancy levels within the building. This prediction is then used by a knowledge based system to make "intelligent decisions" on the zone control of HVAC and lighting. This allows the HVAC and lighting systems to tune themselves to the occupancy patterns of the building instead of following set time cycles. HVAC levels can be relaxed for very sparsely occupied areas of the building at certain times of the day to save energy. The case study used data supplied by the Estates Department of Lloyd's building in central London, which already has a very advanced building management system controlling HVAC and lighting. A building services computer-aided design package has been used to predict savings.

The work has shown that the application of neural networks provides a self-training methodology for occupancy prediction. The nature of neural-network prediction can reduce the number of occupancy sensors required by learning patterns rather than set occupancy levels. In conjunction with knowledge based systems, it has been shown that improved energy management control can be implemented to control HVAC and lighting to accurately fit the occupancy profile of the building.

Home Automation in the Center of Europe: The Belgian Experience

G. Klepfisch, Belgian Center for Domotics, Brussels, Belgium

"Domotics" is a new composite word based on the Latin "domus" (house) and "electronics". It is synonymous with building automation, which is the combination of house building and high technology. The word has not yet passed into common speech, perhaps because it is applied to the construction of the future. To build a house, you need a team of specialists from many different sectors, including electronics. These people got together and established the Belgian Centre for Domotics. For a long time, the building industry was known as a relatively stable, even conservative, sector where new technology received little or no chance for acceptance. Times change. The building sector today is challenged by a large variety of new technological developments.

Domotics is a case in point. Smart buildings have become a household work; we speak of the IQ of a building. The technological quality of a building can be measured by the services it renders to its occupants and owners. These services include: safety of people and goods, stability, whether services are permanent or not, flexibility, communication and information exchange, living comfort, and system integration and coordination. A building with a high IQ is, consequently, a building that gets a high score on the evaluation of services rendered.

Technological progress is good only when it is put to good use. The question is "How can it, in my own environment and in the world at large, contribute to a fuller life?" The first thing is not to want to take too many steps at once but to keep in view the wishes of the general public. What do people expect domotics to do for them?

A smart house will need to perform particular social functions, such as child supervision and supervision for the handicapped and the elderly. It is expected to monitor itself (lighting, heating, safety, etc.) and to inform the owner or occupant correctly when things go wrong. Practical considerations are made concerning: creating ideal living conditions for the home in terms of heating, air-conditioning, perhaps cooling; energy management; lighting management with regard to natural light conditions; burglar protection; home safety (electricity, gas, water); child supervision and assistance for the handicapped and the elderly; and gathering information by means of databanks.

International Standardization for Ventilation and Thermal Comfort Requirements

B. Olesen, Virginia Polytechnical Institute, Blackburg, VA, U.S.A.

The purpose of most buildings is to provide a comfortable and healthy indoor environment for the occupants. To obtain this, criteria for the design and performance of buildings and their systems as well as their impact on the indoor environment must be established. Serious efforts are being made on the national and international level to revise existing standards or establish new ones, which include guidelines for an acceptable indoor environment. The most important standards are being developed by the International Standards Organization (ISO), European Committee for Standardization (CEN), and ASHRAE. This paper will give an overview of existing requirements and ongoing revisions of ISO, CEN, and ASHRAE Standards. The Standards are similar but show at some points significant differences, which will be discussed.

Sanitary and Hygienic Aspects of Floor-level Air Distribution

L. A. Balandina, Institute Proyektpromventilatsia, Leningrad, Russia
L. V. Puvlukhin, All-Union Research Institute for Labor, Leningrad, Russia

In heat loaded rooms with removable metal flooring, it is expedient to use floor-level air distributors to ensure fast damping of supply jets. This air distribution method is economically advantageous but needs greater attention to sanitary and hygienic working conditions for occupants, which restricts its applicability, especially to cooling rooms.

To supply air into the working area in the upward pattern, taking into account specific features in design and layout solutions for removable metal floors, floor air-distributing panels 500 x 500 mm in size have been worked out in two versions: cast aluminum panels and drop-forged steel panels. To develop methods for designing air conditioning systems using floor air-distribution devices, technical testing and a sanitary and hygienic study have been performed in the laboratory and under full-scale conditions in a computer room.

The results have allowed the definition of specifications for floor-level air distributors, principles of the lean-on air flow developing along the floor surface, zones of air temperature, and velocity combinations that are optimum and permissible for a human being in relation to their design values at the outlet. The use of floor air distributors for regimes of both air heating and air cooling of rooms allows the design air exchange to be reduced 40% with corresponding savings in heat and electricity. Removable floors also save metal by excluding a system of supply air ducts.

Climate Control for the Future: ISO Standards 7730, 7243, and 7933

R. De Meyer, Colt International, Mechelen, Belgium

Poor working conditions have a negative influence on productivity, accidents, and absenteeism. To create a safe working climate, a reliable image of different influences defining thermal comfort should be formed. A number of ISO Standards (International Standards Organization) are set up so as to judge, in an objective way, the effect of the environmental climate on the human being.

ISO 7730 deals with average environmental conditions and handles concepts such as PMV value (predicted mean vole) and PPD value (predicted percentage of dissatisfied). With the help of labels, defining the metabolism and Clo-factor, and by measuring air temperature, average radiation temperature, relative air speed, and partial water vapor pressure, one can predict the thermal perception. ISO 7243, "Hot environmental conditions", uses the WBGT index (wet bulb globe temperature) to evaluate whether one stays above or beneath the assumed value. The danger of a heat stress situation exists when the WBGT index approaches or exceeds the limit value. In that case, a more detailed study and an analysis of the situation will be carried out. In that case, ISO 7933 also produces in detail which steps should be taken to restrict or prevent all harmful consequences to the relevant person.

Action on Indoor Radon in France

A. Rannou, P. Hubert, M. C. Robé, M. Roy, and M. Tirmarche, Institut de Protection et de Sureté Nucléaire (IPSN), Fontenay Aux Roses, France

Radon is a naturally occurring, radioactive gas considered a major risk as an indoor pollutant in temperate climates. IPSN has an ongoing program designed to provide the key elements of a strategy to the national authorities to transfer research findings to concerned institutions and to give ad-hoc information to the general public. This paper provides an overview of the different actions undertaken in this field. These include: radon surveys in different regions of France to assess the magnitude of the problem throughout the nation, research on the parameters influencing indoor radon, basic studies in physics, development of techniques of measurement and calibration, experimental studies to design methods for radon diagnostics and remedial actions to reduce high indoor concentrations, dosimetry and epidemiological studies, development of documents to inform the public, and analysis of the components of the risk strategy.

The Role of the Maintenance Specialist from Building Conception to Completion

R. Jacobs, N. V. Montenay, Brussels, Belgium

This presentation will describe the input that a maintenance specialist can provide to different stages of a building project. During the conception stage, the maintenance specialist can provide assistance in procedure selections for energy efficiency and comfort, health and environment, cost-effective maintenance, and security. During installation, the specialist can advise on the choice of material with regard to the following: energy efficiency, reliability, performance, health and environment, and cost-effective maintenance. The maintenance specialist also can provide input for equipment selection and programming, for example, in the determination of the number of necessary control panels for security, energy, and comfort.

The presentation will conclude with a discussion of possible objections of project directors and installers.

Closing Session: 15:30-16:30

Conference Conclusions

C. Bieva, CDH Larem, Brussels, Belgium

Panel discussion.

Notes